Historical Patterns in Salvage Data

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Introduction

In an effort to reduce environmental impacts, fish are screened, collected and transported back to the Delta from both the state and federal water projects at their points of diversion (Brown et al. 1996). Every two hours samples of the screened fish are collected, identified, measured and counted. These counts are then multiplied to estimate the number of fish that were processed by the salvage operation. The volume of water sampled by the salvage operation is greater than the volume of water sampled by any other sampling program so the numbers of fish sampled are often much greater. These data sets cover several decades and involve very frequent sampling. However, the sampling occurs at only two closely spaced geographic sites and species and population vulnerability varies greatly with variations in river flow and export operations and the distribution, size and abundance of fish species. Thus, it is often difficult to interpret patterns in the salvage dataset.

Salvage numbers are a fraction of the number of fish entrained. First, fish less than 20mm in length are not effectively salvaged and are not included in estimates of salvage. Pre-screen losses of salmonids have been estimated at the state facility several times and it seems that a very high percentage of salmonids entrained into Clifton Court Forebay are never collected at the salvage facilities (Brown et al. 1996). No estimates are available for the pre-screen losses of pelagic fishes. Information on screening efficiencies is very limited. Thus, salvage is, at best, a rough index of annual and seasonal variability in the actual entrainment occurring at the facilities.

Data

Salvage data were compiled from both facilities for the years from 1994 to 2005. The analyses were limited to this time period in order to allow comparison of pre-decline and post-decline patterns while staying within the consistent operational constraints of the 1995 WQCP. Data were included for the four pelagic species of concern and for two taxa without a pelagic lifestage – inland silverside and a general ‘centrarchid’ category representing largemouth bass and various sunfishes.

Results

Summarizing total salvage for each water year indicated little evidence of significant changes in the most recent years; most species peak annual salvage occurred between 2000 and 2002. In the late 1990s and 2000, salvage of several species increased when abundance in the Fall Midwater Trawl increased. It was, therefore, somewhat surprising to see little evidence of a decline in salvage around 2002 when abundance in the Fall Midwater Trawl Survey appeared to have declined by an order of magnitude. This was particularly marked in the data for threadfin shad, which had shown the steepest decline in abundance in trawls but was at record abundance in the salvage from 2001-2005 (Table 1; Table 2).

	Striped Bass	Threadfin Shad	Longfin Smelt	Delta Smelt	Inland silversides	Centrarchids
1994	2455514	1786433	6411	43580	59364	169101
1995	1608433	1378989	112	2632	73754	253755
1996	827813	1919756	293	45733	16824	121374
1997	1507075	3625153	1132	43931	40806	281983
1998	673887	7483046	742	1269	95569	141851
1999	2429470	2995687	805	154651	17294	48278
2000	3523346	1986433	1908	113333	81100	171632
2001	2234087	10488542	6642	24313	109700	113177
2002	1546861	5862902	97734	66548	109811	97947
2003	1013491	6484838	5316	40584	70431	189083
2004	813669	6026905	981	20589	54539	196735
2005	418919	4800848	219	3724	69151	220441

Table 1. Salvage totals by water year for the pelagic species of concern and two littoral species. Annual totals for many species peaked in wetter years when abundances were higher in the Fall Midwater Trawl (see Table 2).

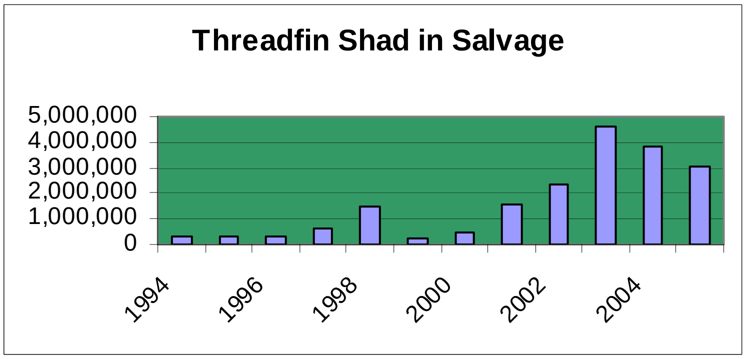
Year	Striped Bass	Threadfin Shad	Longfin Smelt	Delta Smelt
1993	1,557	6,679	798	1,078
1994	1,259	2,305	545	102
1995	484	3,337	8,646	899
1996	392	4,758	1,388	127
1997	568	15,268	690	303
1998	1,224	5,748	6,654	420
1999	541	7,527	5,242	864
2000	390	12,977	3,438	756
2001	731	14,402	247	603
2002	71	1,753	707	139
2003	108	1,956	191	210
2004	53	1,301	190	74

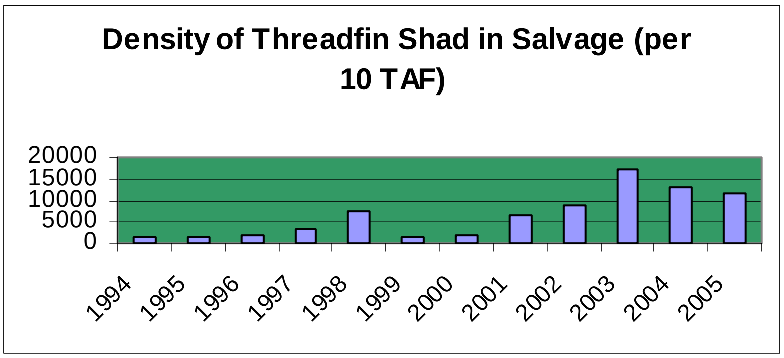
Table 2. Abundance indices for pelagic species in the Fall Midwater Trawl.

Examination of the monthly data indicated that, for all species considered, salvage during winter (November-March) showed a pattern like that of threadfin shad – i.e. a strong increase in salvage despite sharp decreases in apparent abundance in the fall midwater trawl. This pattern is apparent across the full range of abundances and salvage numbers – threadfin shad are salvaged in the millions whereas only a few hundred longfin smelt are usually collected. In the following figures the total wintertime salvage for each species is presented first, then the salvage density (total salvaged/total amount of water exported Nov-Mar). Finally, for each species, the salvage density is divided by the preceding value of the Fall Midwater Trawl for that species to yield an index of their salvage density in relation to abundance.

Sharp increases in all three measures of wintertime salvage for all four species are apparent from the graphs. For striped bass, delta smelt and threadfin shad these upswings in salvage density in relation to abundance occurred first in 2003, although the relatively high abundance of delta smelt produced peaks in salvage density in earlier years. For longfin smelt the first year of increased salvage, especially in relation to abundance was 2002.

For delta smelt and longfin smelt these wintertime peaks are mostly comprised of the adults moving upstream to spawn. For striped bass, these peaks are mostly the juveniles produced during the preceding spring and are still several years away from spawning. For threadfin shad these are probably a mixture of all age classes.





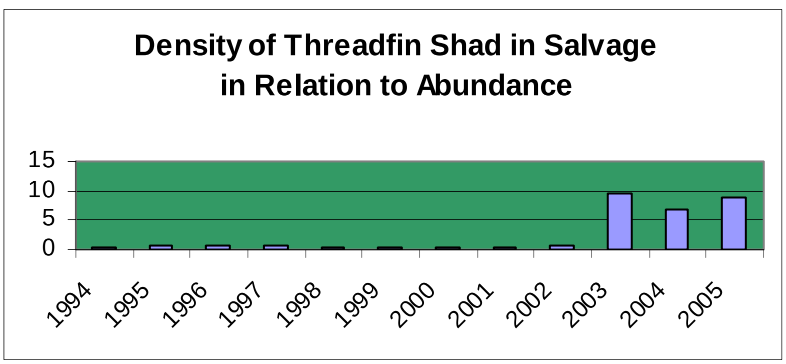


Figure 1, a,b,c. Total November-March salvage of threadfin Shad, salvage density and salvage density in relation to preceding FMWT abundance.

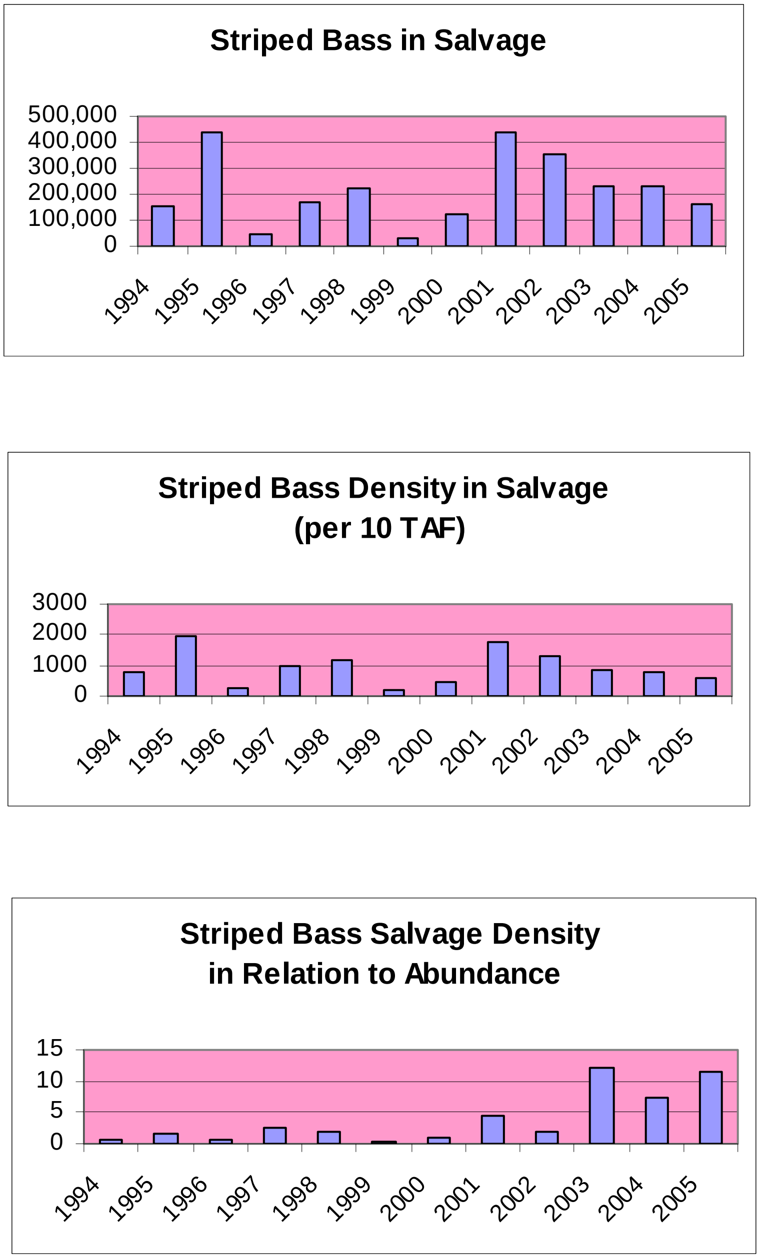
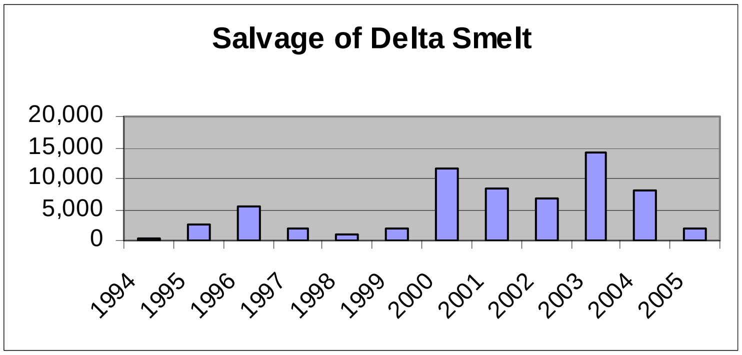
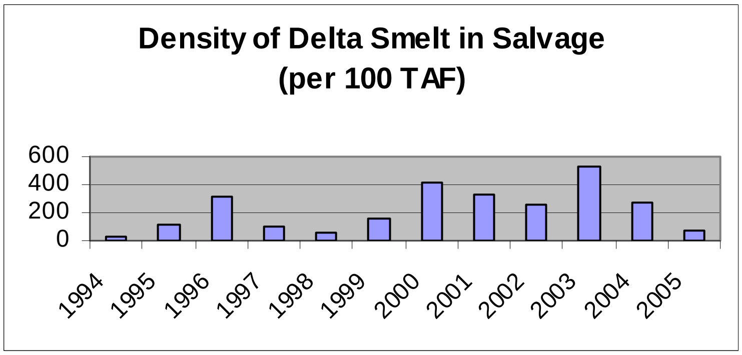


Figure 2, a,b,c. Total November-March salvage of striped bass, salvage density and salvage density in relation to preceding Fall Midwater Trawl abundance.





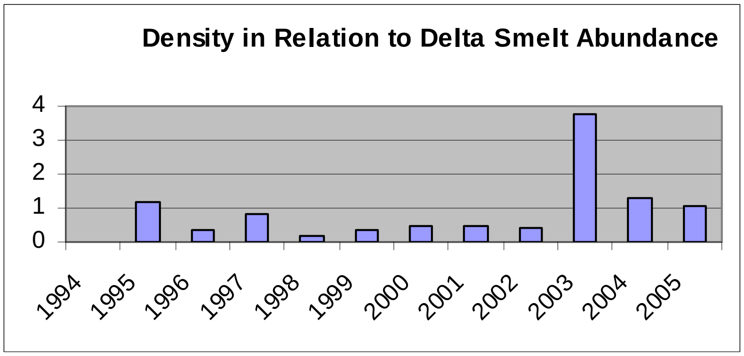
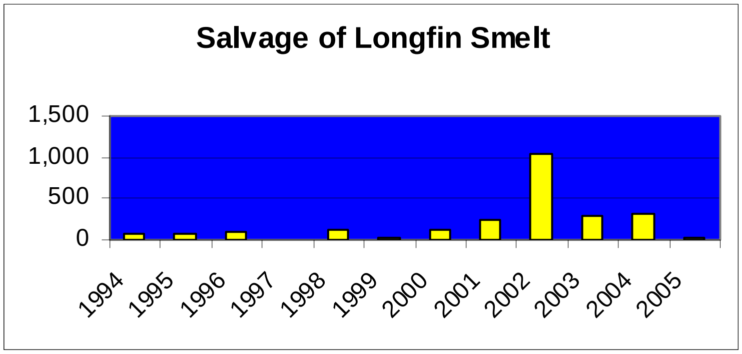
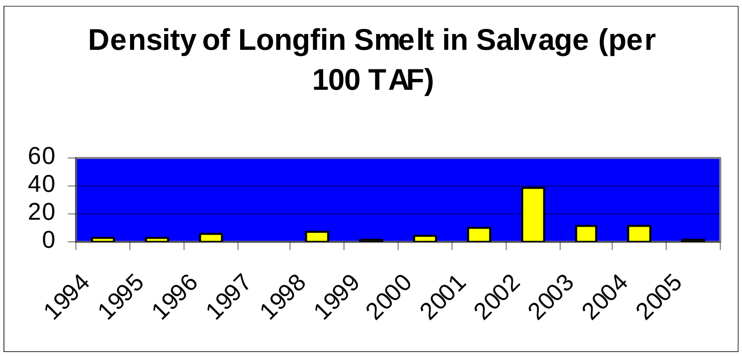


Figure 3, a,b,c. Total November-March salvage of delta smelt, salvage density and salvage density in relation to preceding Fall Midwater Trawl abundance.





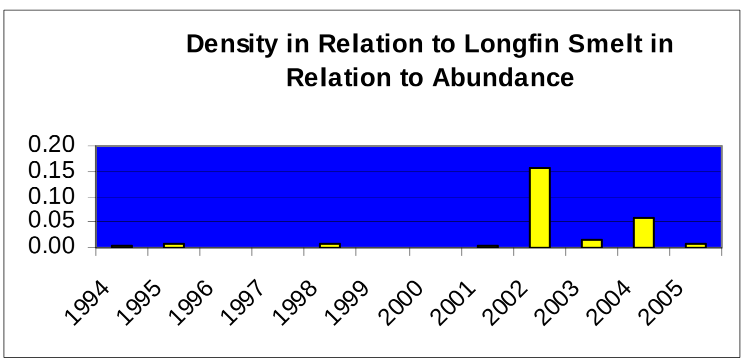
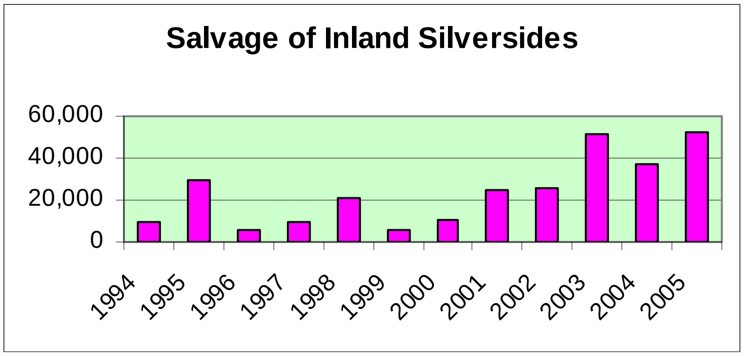


Figure 4, a,b,c. Total November-March salvage of longfin smelt, salvage density and salvage density in relation to preceding Fall Midwater Trawl abundance.

Of particular surprise was the appearance of a very similar pattern in the salvage of the two ‘counter-example’ species included: inland silversides and ‘centrarchids.’ We have not yet developed abundance data for these species so only the first two measures are presented.



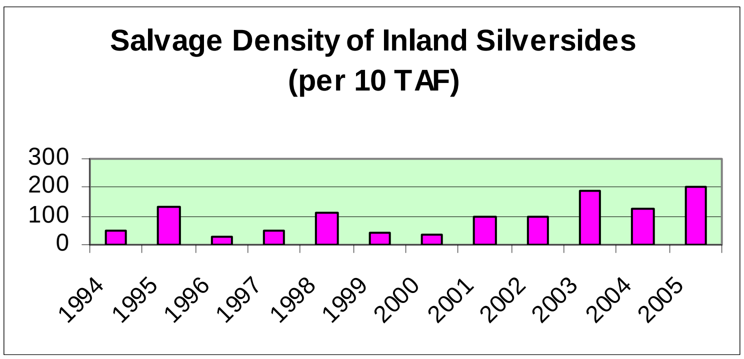
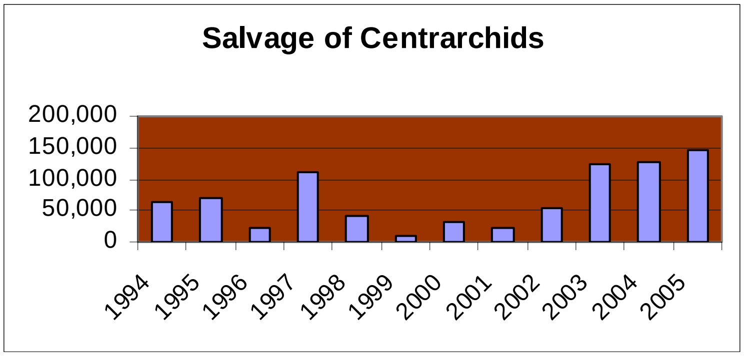


Figure 5, a and b. Total November-March salvage of inland silversides and salvage density.



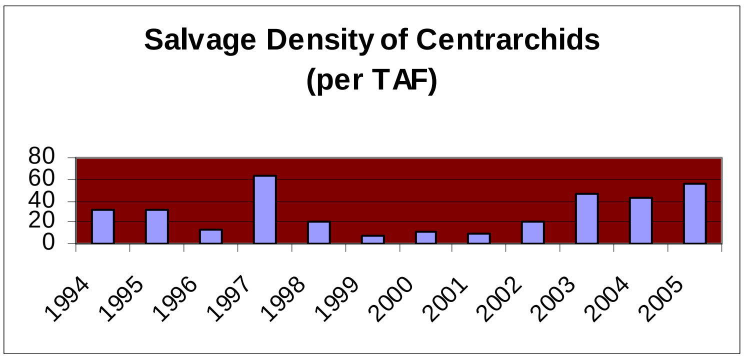


Figure 6, a and b. Total November-March salvage of centrarchids and salvage density.

Possible explanations for increased salvage in recent years of decreased abundance

Operational changes at the salvage facilities

Increased efficiency at the salvage facilities or decreased pre-screen losses could produce the observed increases in salvage. Given the scale of decrease in abundance of the pelagic fishes, these changes would have to be very large. Discussions with personnel familiar with the salvage operations suggested no change in methods or conditions of the salvage facilities that could explain these patterns. Repairs and experiments at the federal facility may have both increased efficiency and decreased pre-screen loss to predators, but such impacts were expected to be minor. Separate analysis of data from each facility may lead to a better ability to identify operational changes that may have coincided with the observed salvage patterns.

Biological changes of the fish or their food

Increased susceptibility to entrainment could explain the observed changes in salvage. Studies of histopathology and disease in pelagic species (Appendix A: Teh 2005 and Ostrach 2005) indicate that many individuals of pelagic species in the Delta show lesions, parasites or other signs of impaired health. Poor feeding success (Appendix A: As reported by Bennett 2005) could slow growth and produce weakened fish during spawning movements or decreased tolerance to thermal stress. Anecdotal evidence from the salvage facilities suggests a higher incidence of striped bass in poor condition. Examination of the health of fish from the salvage, and comparison with fish collected elsewhere would offer one powerful approach to determine whether salvaged fish represent a weakened portion of the population.

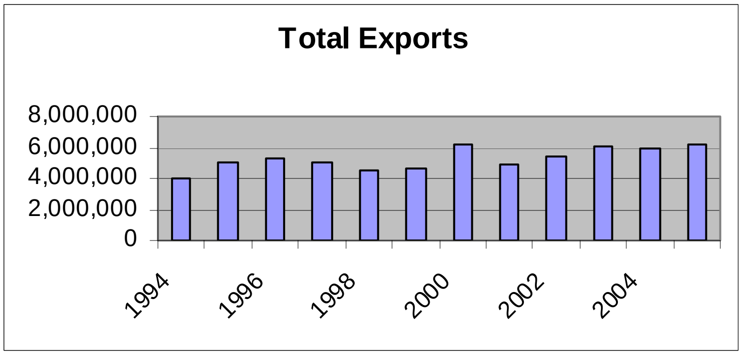
It may also be that changes in the chemical or physical environment have reduced the suitability of other parts of the Delta in wintertime and produced a concentration of fish or their food in the south Delta. Tracking wintertime peaks of abundance of fish and food could determine if such mechanisms are at work. Recent studies have focused on spring and summertime conditions. Future work may need to address wintertime feeding success of older fish. Comparison of feeding success of salvaged fish from fish elsewhere in the Delta could also address this issue.

Hydrodynamic influences that could alter the distribution of fish or their food

Changes in flows, barrier operations and export operations have the potential to change or expand the areas of the Delta from which water is drawn to the salvage facilities.

Peak flows on the San Joaquin River have decreased in size and frequency in recent years (Appendix A: Simi and Ruhl 2005). In addition, gate operations in the south Delta have increased by about fifty days per year (Appendix A: Simi and Ruhl 2005).

Another significant change in recent years is a sharp increase in the volume of total winter-time exports (Figure 7a). Most of this increase has occurred during the winter when salvage has increased (Figure 7b). However, the increase in density at salvage, which was shown by all species examined, indicates that the salvage increase is not explainable as a simple increase in volume of exports.



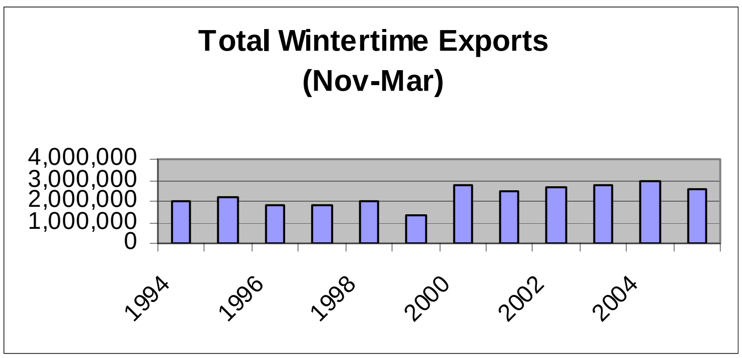


Figure 7a,b Total annual and total wintertime exports. Both Projects combined. Data from DAYFLOW database

If one pictures the export projects as a pump sampler of the Delta, then an increase in pumping intensity would be expected to produce an apparent increase in fish density as both the strength of the pull and the area affected expand. To investigate this effect we graphed the results of DSM-2 particle tracking modeling (Kimmerer and Nobriga unpublished data; basic model description in Appendix A: Sommer et al.) done under artificial hydrology conditions that can be generalized to any time of year to determine the theoretical nature of the relationship between the volume of exports in relation to inflow (the E:I ratio of the 1995 WQCP) and particle entrainment. In each of the simulations shown in Figure 8, the modeled particle insertion location (Bacon Island or Twitchell Island) started with 5,000 particles. Thus, each model run had an equivalent particle 'density'. The fraction of particles subsequently entrained into the export facilities is presented. This can be thought of as the export facilities' "perception" of the particle density. The results show that for a site close to the export facilities (Bacon Island), virtually all particles are taken in at all E:I ratios greater than 20%. Thus, the model results suggest that the facilities provide a more accurate estimate of Bacon Island particle density at E:I ratios greater than 20%. For a more distant site (the mainstem San Joaquin River at Twitchell Island) the density estimate improves linearly as a function of E:I ratio (Figure 8).

Given these modeling results, we examined the actual E:I ratios in recent winters. The average November-March E:I ratio for 1994-2000 was 24% whereas the average for 2001 to 2005 was 36% (Table 3). The most striking difference from water year 1995-2005 was the general lack of very low (< 20%) export:inflow ratios for the 2001-2005 period (Figure 9). These results suggest that recent-year changes in exports in relation to inflow would change the fate of modeled particles and by extension, probably increase both fish salvage and fish salvage densities at the facilities. Virtually all particles close to the export facilities would be entrained, while almost twice as many particles could be entrained from more remote sites (e.g., Twitchell Island). Combined with decreases in San Joaquin flow peaks and increased use of agricultural barriers, these results suggest Delta hydrodynamics may have been substantially altered during the last 5 years. Although these results provide a likely hydrodynamic mechanism for the recent increases in wintertime fish salvage, a much more intensive empirical modeling effort is appropriate.

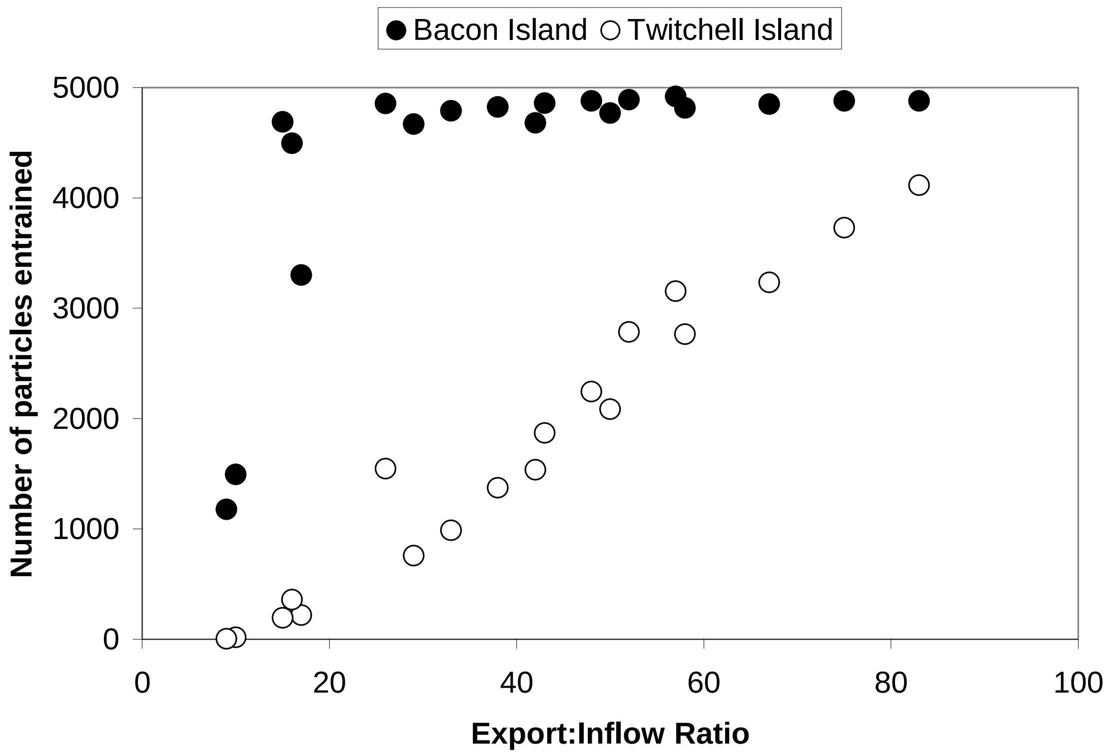
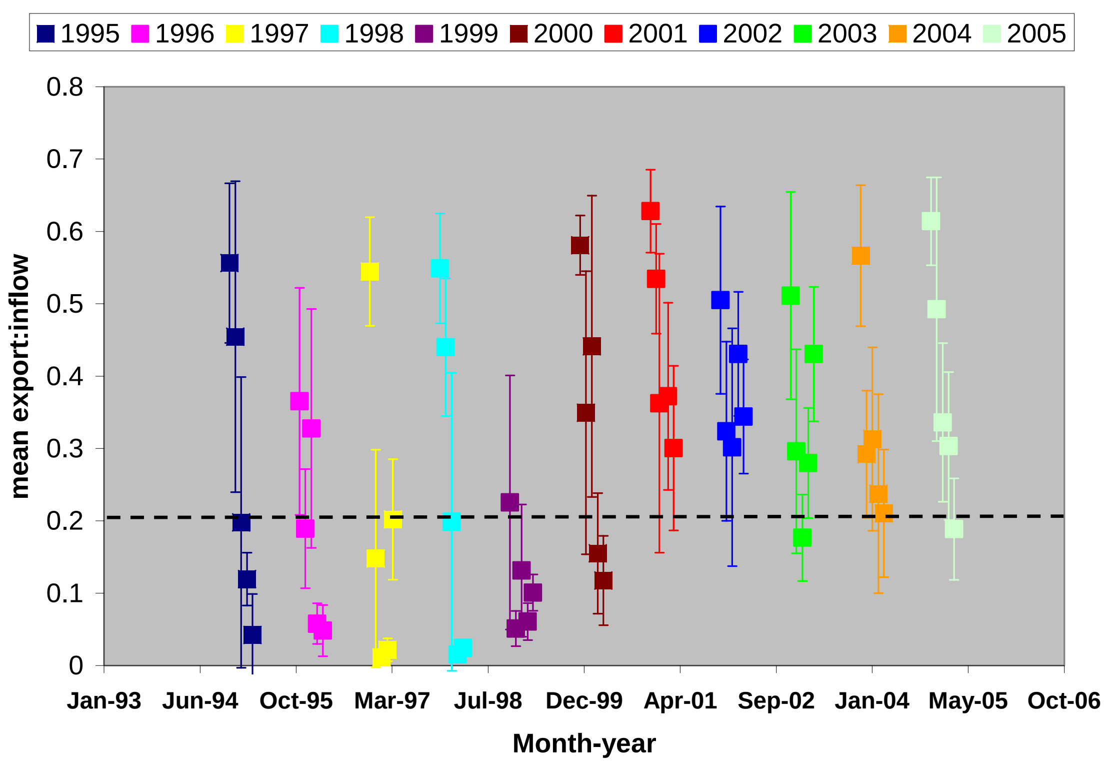


Figure 8. Relationship of E:I ratio to number of particles entrained over a series of particle tracking model runs.

wateryear	Nov	Dec	Jan	Feb	Mar	seasonal average
1994	47	48	35	27	26	37
1995	54	45	20	12	4	27
1996	35	18	32	6	5	19
1997	53	14	1	2	19	18
1998	53	43	19	1	2	24
1999	21	4	12	6	9	10
2000	57	34	43	15	11	32
2001	62	53	36	36	29	43
2002	49	32	29	42	33	37
2003	50	29	17	27	41	33
2004	56	29	31	23	21	32
2005	60	48	33	30	19	38

Table 3. E;I ratios for each month of recent years. Overall average for the 1994-2000 period =24%; average for the 2001-2005 period is 36%.

Figure 9. Monthly average export:inflow ratios ± 1 SD for November-March of water years 1995-2005. Data were taken from DAYFLOW. Note the 2005 data are draft data.



References

Brown, R., S. Greene, P. Coulston, and S. Barrow. 1996. An evaluation of the effectiveness of fish salvage operations at the intake to the California Aqueduct, 1979-1993. Pages 497-518 in J.T. Hollibaugh, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.